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NATIONAL LAW ENFORCEMENT AND BOATER EDUCATION MODEL

By

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1 Introduction

Since March, 1996, the Ohio State University Department of Agricultural Economics has been engaged in a pilot project with the Ohio Department of Natural Resources Watercraft Division to analyze the state's needs for water ways law enforcement and boater education. The purpose of our analysis is to investigate the potential effects of additional law enforcement officers and/or educational requirements on issues of boater safety in the state of Ohio. Our primary goal has been to cast the problem of law enforcement in terms of the social benefits from avoiding injuries, property damages and deaths from boating mishaps. In order to meet this goal, we broke the problem into two components, a model from the national perspective that could incorporate policy differences among the states, and a local model for the state of Ohio that would focus on the allocation of officers among law enforcement districts. This paper deals only with the national model.

To effectively study the problem, it was necessary to obtain data on the experience of a number of states over time in order to control for potentially confounding factors such as alcohol usage, density of boats on waterways, and hours of boater exposure to risk of accidents. A number of data sources were accessed in order to help us accomplish our goal.

2 The Data

We were fairly successful in our data gathering effort, obtaining statistics from a number of sources. The basic data for our analysis came from the United States Coast Guard's reports on accidents and deaths for the entire country, starting from 1987 through 1995. In addition, data were obtained from a national Red Cross study, National Association of State Boating Law Administrators (NASBLA) publications, US Census and from a data request for numbers of patrol officers sent to all states outside of Ohio. We received responses from 20 states to our request for data on number of patrol officers, resulting in a data set of 21 states (including Ohio) for the years 1987-1993. In addition we obtained a full year of 1994 data for all fifty states from a survey that was published by NASBLA. The total data set then consists of 193 individual observations for the years 1987-1994. States participating in the study were Arkansas, Arizona, Connecticut, District of Columbia, Delaware, Georgia, Hawaii, Iowa, Idaho, Kentucky, North Carolina, North Dakota, New Mexico, Oklahoma, Pennsylvania, Tennessee, Texas, Vermont, and West Virginia; after repeated requests we were unable to obtain data from a key neighboring state, Michigan. A response was also obtained from Puerto Rico but was not included. Though not ideal, we feel that the data set contains sufficient information to make good policy predictions for Ohio.

2.1 Descriptive Statistics

Table 1 shows descriptive statistics for the total sample compared to Ohio. The way to interpret total sample statistics is that they represent an "average state" in an "average year". For example, the Per Capita Income for the total sample is the yearly average per capita income averaged over all states in the sample from 1987-1994. The Ohio statistics represent averages over the years 1987-1994.

Ohio's mean numbers of accidents and deaths are higher on average than the other states in the sample (174.5 and 23 vs 108.38 and 15.35), but it is worth noting that there are significantly fewer patrol officers in Ohio (52.67 full time vs 99.41 full time), and Ohio is much larger in terms of number of registered boat, and water acreage (379 thousand boats vs 191 thousand boats, 3.88 thousand water acres vs. 2.26 thousand water acres). In this respect, Ohio compares quite favorably to the overall sample. However, there is one aspect in which Ohio falls short of the overall sample, and that is in property damage dollar estimates. Average annual property damages in Ohio are more than twice the sample average ($927 thousand vs. $416 thousand). On a per accident basis this result is more dramatic, with about $3,850 per accident average in the overall sample and $5,328 per accident average in Ohio. This may be a result of higher speed limits or horsepower restrictions in Ohio than in the other states, but we do not have access to information that could support this hypothesis. This high property damage number warrants more investigation in future research, however, and should be a topic of interest to property insurers.

TABLE 1: **DESCRIPTIVE STATISTICS:**

Total Sample (Includes Ohio)

Variable	N	Mean	Std Dev	Minimum	Maximum
Per Capita Income ($000)	193	15.31	2.68	11.47	24.08
Accidents	193	108.38	169.23	0	1,196.00
Fatalities	193	15.35	17.62	0	93.00
Alcohol Related Acc.	193	7.37	1.08	0	135.00
Alcohol Related Dth.	193	3.09	4.39	0	28
Numbered Boats(000)	193	190.76	183.81	2.86	898.27
Power Boats(000)	193	169.93	175.58	2.33	846.53
Property Damage ($000)	193	415.97	863.75	0	6,642.30
# Students(000)	193	13.71	33.92	0	240.00
Education Hours/Student	193	6.88	3.61	0	20.00
# Full Time Officers	193	99.41	124.35	0	541
# Part Time Officers	193	38.67	74.62	0	360
Land Acres(000)	193	57.67	54.65	0.061	261.91
Water Acres(000)	193	2.26	3.76	0.007	39.90
[Water/Land]•100	193	0.0131	0.009	0.002	0.704

State of Ohio

Variable	N	Mean	Std Dev	Minimum	Maximum
Per Capita Income($000)	9	15.19	0.05	14.68	16.19
Accidents	9	174.50	41.29	124.00	251.00
Fatalities	9	23.00	4.63	19.00	32.00
Alcohol Related Acc.	9	11.88	7.22	2.00	21.00
Alcohol Related Dth.	9	7.25	4.89	4.00	19.00
Numbered Boats(000)	9	379.34	6.20	366.29	385.21
Power Boat(000)	9	295.76	34.52	274.01	380.41
Property Damage ($000)	9	927.45	352.91	487.90	1,711.60
# Students(000)	9	25.76	20.07	1.40	50.90
Education Hours/Student	9	8.00	0	8.00	8.00
# Full Time Officers	9	52.67	6.144	43.00	60.00
# Part Time Officers	9	0	0	0	0
Land Acres(000)	9	40.95	0.00	40.95	40.95
Water Acres(000)	9	3.88	0.00	3875.00	3875.00
[Water/Land]•100	9	9.46	0.00	9.46	9.46

One last area in which Ohio falls behind the other states sampled is in number of boaters (as a percnetage of registered boats) who participate in a boating education course. In the overall sample, 7.19% of boaters take part in a formal boating education course, while in Ohio the percentage is 6.79%. There are 5 deaths per 100,000 boats in Ohio as compared to 8 for the total sample, and 46 accidents per 100,000 boats as compared to 57 for the total. However, in Ohio, alcohol was involved in 31.52% of deaths whereas in the rest of the sample alcohol is implicated in just 20.13% of deaths. Both Ohio and the rest of the sample had alcohol related accidents that were 6.8% of the total accidents.

3 The Model

The objective of our model is to estimate the effects that various policies or combinations thereof will have in decreasing the number of boating accidents and/or deaths occurring within a one year period. There are two primary statistical models for discrete occurrences of events within a given time period. The most well known is the poisson model that estimates the probability that a given number of events will occur within a given time period; in this case the number of accidents and deaths. The poisson model has a major drawback empirically and thus an extension of the model known as the negative binomial model is usually preferable to the poisson. For purposes of estimating the effects of policy decisions on the probability of boating mishaps, we use the following form of the negative binomial regression model:

$$\Pr[Y = y_i] = \Gamma(\frac{1}{\alpha} + y_i)/[\Gamma(\frac{i}{\alpha})y!]u_i^{\frac{i}{\alpha}}(i - u_i)^{y_i}$$

where $u_i = \frac{1}{1+\alpha\lambda_i}$. The model estimates the probability that the number of accidents, or deaths, in a year (Y) equals the actual number observed (y_i). α is a parameter that describes dispersion in the data set such as we might expect to see from statistical differences in the various states in the sample. λ represents the expected number of accidents or deaths estimated from the sample

Note that y_i will be a function of various explanatory variables. In the case at hand, we expect that the explanatory variables will fall into two broad categories: 1) policy variables, and 2) controlling variables. We assume that the same policies and controlling variables are relevant in the case of either accidents or deaths, although they may have different impacts on probabilities. Thus we proceed on the assumption that two different probability models are to be estimated, one for accidents and one for deaths.

4 Model Implementation

As described in the previous section, we use both policy and control variables in estimating our models. The control variables are as follows: per household income level by state and year; boating exposure hours by region; yearly annual per capita alcohol consumption; number of registered boats/acre by state and year; percentage of power boats by state and year; and finally, dummy variables for "northern" and "middle" states which act as a proxy for cultural differences in different regions of the US. The policy variables of interest in this analysis are related to enforcement of boating laws as well as public education on boating safety. Falling under the category of enforcement are numbers of full time patrol officers per state and year per 1,000 boaters, as well as an equivalent variable for part time officers. In addition, we include a dummy variable for any state that has a certification requirement for underage boat operators. Education variables include mandatory education and total hours of education per 1,000 boaters. The results of the estimation are given in Table 2 for accidents and Table 3 for fatalities.

4.1 Model Analysis

In Tables 2 and 3, the variable names, coefficient estimates, standard errors of the estimates, t-ratios and level of statistical significance are reported (Prob$|$t$|\geq x$). In general, we can get an idea of how the various policy and control variables affect the probability of an accident by inspecting the signs of their estimated coefficients. In addition, we have to be concerned with statistical significance of the coefficient estimates: this tells us whether or not the coefficient estimates are significantly greater than zero.

TABLE 2: **Negative Binomial Regression**

Dependent Variable = Accidents Per Year

Log-likelihood= -987.8880

Variable	Coefficient	Std. Error	t-ratio	Prob|t| $\geq$x
Constant	-8.2298	4.625	-1.779	0.0752
Mandatory Education	-0.0822	0.273	-0.301	0.7637
Exposure	0.0047	0.0017	2.748	0.0060
Alcohol Consumption	0.0916	0.0628	1.459	0.1446
Education Hours	-0.0001	0.0006	-0.137	0.8907
Full Time / 1000 Boaters	-0.5709	0.0465	-12.275	0.0000
Part Time / 1000 Boaters	-0.5608	0.1292	-4.340	0.00001
Young Certification	-0.5614	0.1655	-3.392	0.0007
Boats/Acre	-0.2872	0.4882	-0.588	0.5563
% Power Boats	0.0003	0.0006	0.401	0.6885
Income	0.0001	0.00005	1.553	0.1204
Year	0.0980	0.0319	3.070	0.0021
North	-1.0873	0.2015	-5.396	0.0000
Middle	-0.9391	0.1950	-4.817	0.0000
α	0.5391	0.0721	7.483	0.0000

TABLE 3: **Negative Binomial Regression**
Dependent Variable = Deaths Per Year
Log-likelihood= -627.8352

Variable	Coefficient	Std. Error	t-ratio	Prob$\|\mathbf{t}\|\geq$x
Constant	-1.2904	4.699	-0.275	0.78363
Mandatory Education	-0.1184	0.2339	-0.506	0.61285
Exposure	0.0104	0.0022	4.884	0.00000
Alcohol Consumption	0.0534	0.0644	0.830	0.40660
Education Hours	-0.0001	0.0004	-0.136	0.89166
Full Time / 1000 Boaters	-0.6671	0.0918	-7.270	0.00000
Part Time / 1000 Boaters	-0.5023	0.1241	-4.049	0.00005
Young Certification	-0.0825	0.1532	-0.538	0.59025
Boats/Acre	-0.3534	0.6740	-0.524	0.60007
% Power Boats	0.0004	0.0009	0.436	0.66277
Income	-0.00004	0.00003	-1.365	0.17217
Year	0.0251	0.03197	0.785	0.43257
North	-0.7683	0.2294	-3.350	0.00081
Middle	-0.2981	0.1894	-1.574	0.11542
α	0.3988	0.0607	6.572	0.00000

From Table 2, we see that the regression signs for probability of accident are in line with our expectations. That is, mandatory education, number of education hours and mandatory certification of young boaters, along with numbers of full and part time patrol officers will reduce the probability of an accident. However, on closer inspection, we see that only policies that increase patrol officers or require certification of underage boaters will have a *significant* impact on the probability of accidents.

It is also worth noting that although patrol officers significantly impact accident and death rates that their impact is in terms of officers per 1,000 boaters, which in reality may require large changes in numbers of officers to effect a change in deaths and accidents In terms of the control variables, only exposure, year and the north and middle dummy variables significantly affect the probability of accident. Per capita alcohol consumption, though positively affecting probability, is not particularly significant, and the same is true with income.

In contrast to the regression results for accidents, the results for the model for probability of deaths reported in Table 3 is quite different: in this case, it appears that the only policy that would effectively decrease the probability of deaths would be to increase the number of full and part time officers. In addition, the only significant control variables are the "north" dummy variable and exposure. To evaluate the effectiveness of various policies requires simulation of the model under different scenarios.

5 Policy Analysis

The model can be used to predict accidents and death under various policies. For instance, a 10% increase in full time officers per 1,000 boaters leads to a predicted decrease in accidents and deaths of about 1%. Although Ohio averages about 0.14 officers per 1,000 registered boats in Ohio for the years 1987-1994, the recent trend in enforcement has been to reduce the numbers of officers. For instance, in 1987, the number of officers per 1,000 boats is 0.1174 ($\frac{43}{366.289}$), while in 1994 the number grew to 0.1246 ($\frac{48}{385.206}$). This is about a 6% increase in officers per 1,000 boats, and would not be expected to decrease the accident and death rates by even 1% overall. It is worth noting that the other states in the sample have numbers of officers per 1,000 boaters that are much higher than Ohio. On average, there are 0.52 full-time officers per 1,000 boaters and 0.20 part-time officers per 1,000 boaters for the other states in the sample. Looking at Table 4 below, we see that increasing the number of full time officers per thousand boaters in Ohio to the sample average of 0.52 would significantly decrease the numbers of both accidents and deaths. Since Ohio presently has no part time officers, adding part time personnel to the 0.20 level of the sample mean would also reduce accidents and deaths, though not nearly as dramatically as would the addition of full time personnel.

In terms of accidents, the policy of requiring certification of young boaters appears to be highly effective. Although we do not have estimates of the cost that would be incurred to undertake such a policy, our model predicts that accidents could be reduced by about 42% by certification. However, this may be misleading in that our model cannot correctly account for differences in the age distribution of boaters in the sample. Thus, it may be the case that the states requiring under aged certification may be those with large numbers of youthful boaters. Nonetheless, even if certification of young boaters decreased accidents by only 20%, the average reduction in accidents would be 35 per year, or in dollar terms, about \$186,480 per annum. Note that this figure does *not* include costs of injuries such as medical care payments or time off the job, suggesting that the benefits of this policy as estimated are quite conservative. We would also point out that although certification of youthful boaters does not enter significantly into the model for deaths, the dramatic decrease such a policy brings about in accidents leads us expect to see the probability of deaths decreased as an indirect effect.

Estimating the benefits of avoided deaths as a result of the policies described here is slightly more subjective. Several economic studies of the value of life in recent years suggest that the value of a human life in terms of lost productivity is, on average, about $6.2 million (Moore and Viscusi, 1988 and 1990). Thus, even a 1% decrease in deaths (2.3 fewer per year on average) would have a societal benefit of about $14.26 million per year. We can also add to this some other avoided costs from adding patrol officers: first, there may also be property damage involved in an accidental death; second, officers play a major role in the education of the boating public. Although education does not show up as a significant variable we still believe that there is a very real positive external effect due to education of boaters.

Table 4: **Boating Safety Policies**

ACCIDENTS

Policy Action	**Expected % Decrease**
Certify Young Boaters	42.96%
Increase Number of Full Time Officers	19.94%
Increase Number of Part Time Officers	10.60%
Increase Full and Part Time Officers	28.09%
Increase Officers and Certification	58.98%

DEATHS

Policy Action	**Expected % Decrease**
Increase Number of Full Time Officers	22.43%
Increase Number of Part Time Officers	0.78%
Increase Full and Part Time Officers	29.89%

6 Summary and Conclusions

Our study of national boating policies has demonstrated that there is a very real and important impact on accidents and deaths by increased enforcement of boating safety laws. In addition, we have discovered that mandatory certification of youthful boaters also can significantly reduce the number of accidents annually. Compared to other states in the study, Ohio has significantly fewer patrol officers. However, that Ohio has about $\frac{1}{3}$ fewer patrol officers per 1000 boats than the sample but has accident and death rates per 100,000 boats that are lower than the sample one might infer, that Ohio's enforcement officers are more efficient than the sample. Since Ohio has already demonstrated an effective patrol force, it would make sense to continue to increase effort in this area. Since our model does in fact estimate probabilities of deaths and accidents from the total sample with its less efficient patrol force, it is quite likely that decreases in Ohio from bolstering enforcement efforts might have an even greater impact than the model predicts.

We conclude that Ohio should carefully consider the costs of implementing youth certification programs to see if the costs are no greater than the benefits estimated by this model. We further recommend that Ohio consider the addition of patrol officers. When the second stage of this study is completed, we should be able to further recommend where additional officers should be deployed.

Average # Accidents/County/Year
1993-1995

UNDER-PREDICTED COUNTIES

	ACCIDENTS		
	Actual	Predicted	Under Prediction
Delaware	17.3333	4.5435	-12.7898
Lorain	19.6667	12.3810	-7.2856
Cuyahoga	32.6667	27.9887	-4.6780
Portage	5.6667	2.7085	-2.9582
Wood	1.0000	-1.8747	-2.8747
Defiance	0.6667	-0.9953	-1.6619
Gallia	0.6667	-0.8818	-1.5485
Brown	1.6667	0.2743	-1.3923
Tuscarawas	2.0000	0.7728	-1.2272
Geauga	0.3333	-0.6903	-1.0237
Washington	1.0000	-0.0198	-1.0198
Guernsey	5.0000	3.9906	-1.0094
Knox	0.6667	-0.3106	-0.9772
Clermont	4.6667	3.7308	-0.9359
Licking	3.3333	2.5381	-0.7952
Crawford	0.0000	0.7354	-0.7354
Ashland	1.6667	0.9425	-0.7242
Marion	0.0000	0.7150	-0.7150
Madison	0.6667	0.1092	-0.5575
Coshocton	0.3333	-0.1683	-0.5016

Average # Accidents/County/Year

OVER-PREDICTED COUNTIES

	ACCIDENTS		
	Actual	Predicted	Over Prediction
Preble	0.0000	1.0051	1.0051
Wayne	0.0000	1.1252	1.1252
Ashtabula	11.0000	12.1254	1.1254
Hamilton	3.6667	4.8063	1.1396
Butler	1.0000	2.1521	1.1521
Noble	0.6667	1.8365	1.1698
Shelby	0.0000	1.1832	1.1832
Perry	0.0000	1.1871	1.1871
Montgomery	3.6667	4.8596	1.1929
Trumbull	4.0000	5.2125	1.2125
Lawrence	0.6667	1.9946	1.3279
Clinton	0.0000	1.3858	1.3858
Ottawa	32.3333	34.0653	1.7319
Lucas	13.0000	15.2763	2.2763
Franklin	1.3333	3.9760	2.6427
Stark	0.3333	3.1388	2.8055
Mahoning	1.6667	4.4796	2.8130
Lake	11.3333	14.4070	3.0736
Muskingum	2.3333	5.9090	3.5750
Logan	4.3333	0.4666	3.8668
Highland	1.3333	5.4338	4.1004
Richland	0.3333	4.5802	4.2468
Pickaway	6.3333	1.7576	4.5758
Auglaize	0.0000	5.1869	5.1869

STATE MODEL FOR DEATHS

Dependent Variable: Deaths per County per year

F Value	Prob>F	R-square	0.4312
14.149	0.0001	Adj R-sq	0.4007

Variable	Parameter Estimate	T for H0: Parameter=0	Prob > |T|
Intercept	0.02634	0.381	0.7033
Acres of Inland Lakes	0.00001	0.188	0.8510
HP Index	-0.00001	-0.444	0.6572
# of Inland Rivers	-0.02328	-0.593	0.5535
Miles of Lake Erie Shoreline*	0.04163	6.920	0.0001
OH River Shoreline (Kentucky)	-0.00141	-0.242	0.8092
Total Boats Registered	0.00001	0.390	0.6972
Jet Skis Registered	-0.00139	-1.502	0.1345
Power Boats Registered	0.00005	0.363	0.7167
Education Hours/Boat	-1.94776	-1.141	0.2551
Patrol Hours/Boat	1.08106	1.347	0.1793
Marine Hours/Boat	0.00002	0.501	0.6171
Water/Land Ratio	-0.15838	-1.198	0.2323

Average # Deaths/County/Year
1993-1995

UNDER-PREDICTED COUNTIES

	DEATHS		
	Actual	Predicted	Under Prediction
Tuscarawas	1.00000	0.12326	-0.87674
Warren	1.00000	0.15560	-0.84440
Lucas	2.00000	1.22099	-0.77901
Morgan	0.66667	0.07951	-0.58716
Logan	0.66667	0.19945	-0.46722
Athens	0.33333	0.05307	-0.28027
Coshocton	0.33333	0.07395	-0.25939
Medina	0.33333	0.07629	-0.25704
Cuyahoga	2.00000	1.74922	-0.25078
Clark	0.33333	0.11075	-0.22258
Perry	0.33333	0.11342	-0.21991
Muskingum	0.33333	0.11493	-0.21841
Hamilton	0.33333	0.14282	-0.19052
Guernsey	0.33333	0.16352	-0.16981
Erie	2.00000	1.84123	-0.15877
Ashtabula	1.33333	1.19924	-0.13409
Noble	0.33333	0.24623	-0.08710
Lorain	1.00000	0.91569	-0.08431
Gallia	0.00000	-0.07588	-0.07588
Auglaize	0.00000	-0.07144	-0.07144
Huron	0.00000	-0.04430	-0.04430
Adams	0.00000	-0.00960	-0.00960
Madison	0.00000	-0.00953	-0.00953

Average # Deaths/County/Year
1993-1995

OVER-PREDICTED COUNTIES

	DEATHS		
	Actual	Predicted	Over Prediction
Paulding	0.00000	0.10119	0.10119
Greene	0.00000	0.10459	0.10459
Lawrence	0.00000	0.11482	0.11482
Knox	0.00000	0.12043	0.12043
Williams	0.00000	0.12110	0.12110
Richland	0.00000	0.12115	0.12115
Delaware	0.00000	0.12691	0.12691
Clinton	0.00000	0.13113	0.13113
Trumbull	0.00000	0.13370	0.13370
Sandusky	0.00000	0.13545	0.13545
Licking	0.00000	0.14140	0.14140
Clermont	0.00000	0.15545	0.15545
Fairfield	0.00000	0.16305	0.16305
Portage	0.00000	0.18191	0.18191
Geauga	0.00000	0.21263	0.21263
Mahoning	0.00000	0.22313	0.22313
Highland	0.00000	0.22699	0.22699
Lake	0.66667	0.90511	0.23845
Harrison	0.00000	0.24851	0.24851
Stark	0.00000	0.29652	0.29652
Franklin	0.33333	0.63429	0.30096
Ottawa	2.66667	3.06969	0.40302
Summit	0.00000	0.41771	0.41771